Dkt. 76294-PCT-US/RDK

IN THE UNITED STATES DESIGNATED/ELECTED OFFICE

UNITED STATES UTILITY PATENT APPLICATION

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TITLE: AUTOMOBILE BODY PART

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10/578985
11 MAY 2006

AUTOMOBILE BODY PART

The invention concerns a car body part of sheet metal of an aluminium alloy type AlMgSi, and a car body or component of a car body with at least one first component of sheet metal of the first aluminium alloy and at least one second component of sheet metal of a second aluminium alloy, where the first and second aluminium alloys are of type AlMgSi, and after artificial ageing of the body or body part, the second component in comparison with the first component has lower mechanical strength values.

For car body parts, car bodies or components of car bodies, artificial ageing takes place for example under the annealing conditions during paint baking or in a separately performed heat treatment.

The growing importance of the production of lighter cars with the purpose of energy saving has led to the development of a large number of aluminium alloys for car applications.

Different components in a car usually require different properties. For example, an aluminium alloy for outer panel applications must be easily deformable in order to allow stretch drawing, deep drawing and bending, and at the same time achieve a high strength after paint baking.

In Europe, for outer panel applications in particular for engine bonnets, already AlMgSi alloys are used, e.g. the alloy AA 6016, to a fairly great extent.

In particular, with regard to scrap metal reuse and recyclability, it would be particularly advantageous and suitable if for all aluminium panel applications in the body, aluminium alloys could be used which belong to the same family of alloys. US-A-4 082 578 and EP-A-0 811 700 disclose aluminium alloys of type AlMgSi for inner and outer panel applications in car bodies.

Aluminium alloys in the structural area of a vehicle improve the driving behaviour

(vehicle rigidity, axle load distribution, centre of gravity etc.). Such constructions can also have a high energy absorption capacity in the event of a crash. EP-A-1 165 848 discloses structural components made of sheet metal from an AlMgSi alloy.

In particular in Europe, the reduction of injury risk in car accidents has high priority. Due to improvements in car safety, this objective has been achieved very effectively. So far, however, very little has been done to reduce the severity of injuries to pedestrians and motorcyclists who hit the front of a car in an accident. Substantial improvements can be achieved by constructing the front parts of cars with corresponding energy absorption behaviour.

Pedestrian protection measures on car bodies can be very effective in preventing serious and fatal injuries from collisions in the medium speed range. In most traffic accidents with pedestrians, a car collides frontally with the victim. The injury to the pedestrian is only partly caused by the initial impact. In many cases the pedestrian's torso bends and his head hits the bonnet.

Most head injuries are caused in adults by the upper end and in children by the front part, of the engine bonnet. The front edge of the bonnet is particularly critical in relation to injuries in the thigh or hip area. Detailed changes in the panel construction of the bonnet edge are necessary to reduce the rigidity and create sufficient crumple depth. This can be achieved by weakening or taking back the inner panel reinforcements on the bonnet, the bonnet closure and the closure cross braces.

By various active and passive measures, front panels and other large area body elements of cars have been made "softer". Here, the components are designed or actively modified so that in an impact they can absorb a large part of the kinetic energy by plastic deformation. These measures lead to fewer serious injuries.

Passive measures include the design, construction and material. In relation to the material, various material compounds are known e.g. sandwich constructions with

foam materials. So far, however, no tests have been undertaken on the use of relatively soft aluminium alloys.

The invention is based on the object of creating a car body part and car body or component of a car body of the type cited initially which, as well as the common recycling of process scrap in the production of the various components, and simple scrap recycling of the body part in the end of life vehicle, leads to improved impact protection for pedestrians in comparison with solutions according to the prior art.

In relation to the single skin car body part, the object is achieved according to the invention by the presence in the sheet metal of a substantial part of the elements Mg and Si, which are required to achieve artificial ageing in solid solution, in the form of separate Mg_2Si and/or Si particles in order to avoid artificial ageing.

In relation to the multi-skin car body or components of a car body produced from an outer and an inner part, the object is achieved according to the invention by the presence, at least in the sheet metal of the second aluminium alloy before artificial ageing of the body or body part, of a substantial part of the elements Mg and Si, which are required to achieve artificial ageing in solid solution, in the form of separate Mg_2Si and/or Si particles in order to avoid artificial ageing.

The essential core of the invention lies in the use of "soft" components with a prespecified structure, so that - in contrast to "hard" components - under the normal paint baking conditions no or a decreased artificial ageing, respectively, occurs and consequently there is no further or a decreased increase, respectively, in the chemical strength values, but the soft components retain the values previously set by the prespecified structure or do not reach the maximum possible strength level during artificial ageing.

As a hard first aluminium alloy, an alloy is preferred which contains

0.6 to 1.2 w.% silicon

0.3 to 0.8 w.% magnesium
max. 0.8 w.% copper
max. 0.4 w.% iron
max. 0.3 w.% manganese
max. 0.2 w.% vanadium

and production-related contaminants and aluminium as the remainder.

The hard first aluminium alloy comprises in particular the usual body outer skin materials e.g. AA 6016 and AA 6111.

In principle as a soft second aluminium alloy, an alloy identical to the first hard aluminium alloy is used, but in general a composition is preferred with a substantially lower strength level.

As a soft second aluminium alloy an alloy is preferred which contains

0.25 to 0.60 w.% silicon
0.25 to 0.60 w.% magnesium
0.05 to 0.30 w.% copper
max. 0.40 w.% iron
max. 0.30 w.% manganese
max. 0.20 w.% vanadium

and production-related contaminants, individually max. 0.05 w.%, in total max. 0.15 w.%, and aluminium as the remainder.

For the individual alloy elements of the second aluminium alloy, the following preferred content ranges apply:

0.30 to 0.50 w.% silicon
0.30 to 0.50 w.% magnesium
max. 0.20 w.% copper

0.50 to 0.20 w.% iron
max. 0.10 w.% manganese
max. 0.15 w.% vanadium.

The desired strength or softness of the soft second component is set mainly by way of the Mg and Si content of the second aluminium alloy in combination with heat treatment of the sheets produced from the alloy before their shaping into the second components. Heat treatment ensures that the desired low mechanical strength values of the soft second component are substantially unchanged or may only reach a strength level being higher but lying below the maximum possible values, respectively, even after performance of a paint baking cycle on the car body. Depending on performance, the heat treatment causes:

- precipitation of a substantial part of the alloy elements Mg and Si from the solid solution in the form of Si and Mg_2Si particles and their coarsening so that the said alloy elements are no longer available in is entirety for the subsequent artificial ageing, and/or

- prevention of redissolution of the separated Mg_2Si and Si particles so that the alloy elements Mg and Si are also no longer available in is entirety for further ageing during subsequent artificial ageing during a subsequent paint baking cycle.

It is also conceivable to use, instead of a "hard" first component, a "soft" one i.e. a component which cannot be artificially aged, and to adjust the different strength values of the first and second components by way of the concentration of the alloy elements Mg and Si.

"Soft" panels, or sheets of the second aluminium alloy, can be produced in a conventional manner by way of continuous or strip casting with subsequent hot and/or cold rolling, with or without intermediate annealing.

With the conventional manufacturing process of car body sheet from AlMgSi

materials attention is paid that alloy elements which are relevant for the precipitation are practically completely in solid solution after solution heat treatment or before artificial ageing, respectively, and only a part which is unavoidable with the selected manufacturing process and which may be designated as unessential at best is present in precipitated form.

The car body sheet according to the invention differs from this. The part of alloy elements which are relevant for precipitation which are present in precipitated form after solution heat treatment or before artificial ageing, respectively, causes a change of the mechanical strength values which lies outside the deviations from a given nominal value lying within the scope of manufacturing tolerances with a conventional production process. The part of the alloy elements which are relevant for precipitation which are present in precipitated form is therefore to be designated as substantial.

The desired precipitation state of the alloy elements Mg and Si in the sheets of the second aluminium alloy can be achieved in various ways which are already known. Preferred process stages which deviate from the conventional production procedure of AlMgSi body materials and lead to the desired pre-separation of the alloy elements Mg and Si which are relevant for artificial ageing, include the following steps which can be performed individually or in combination:

- No homogenisation annealing of the casting bar, merely heating to hot rolling temperature and immediate hot rolling.

- Performance of a "partial solution annealing" on the sheet, rolled to the final thickness, for a short period at relatively low temperature with continuous annealing in a strip passage oven at a temperature range from around 450° to 520°C for max. 30 seconds, where applicable using mild cooling conditions.

- Performance of a “partial heterogenisation” annealing of the sheet, rolled to the final thickness, with annealing of coils in a chamber oven with a retention time from 1 to 4 h in a temperature range from around 330°C to 400°C.

In principle the second aluminium alloy is selected primarily on the basis of a prespecified strength. The temperature and duration of performance of the above-mentioned annealing which is necessary to achieve a structure state which does not lead to a further or only to a defined limited rise, respectively, in the mechanical strength values on subsequent artificial ageing, are determined for each alloy or application individually from a simple test series.

The lowest strength level results if the part of alloy elements present in solid solution and contributing to artificial ageing is so small that it is to be neglected. For example, in case a specification for a car body part made from sheet requires a defined strength level lying above the minimum strength level for a given alloy composition, the strength level can be adapted with the same alloy composition by selecting a higher part of alloy elements present in solid solution and contributing to artificial ageing or controlling the artificial ageing treatment that only a small part is precipitated as Mg_2Si and/or Si particles, respectively. The car body part is then somewhat less "soft" in favour of a higher strength.

Preferably, the soft second components are inner panels of a body element, in particular a bonnet, and trim parts or structural components or reinforcing elements arranged in the front area of the body. The soft second components can however also be body elements which in conventional car bodies are formed from hard first components. A substantial area of use of the soft second component is hence deep-drawn body parts with good bending behaviour.

A soft component can for example be used as an inner panel of a steel or plastic bonnet, a trim part in the front area of a car (e.g. radiator grille, bumper cover, spoiler etc.) or a structural component or reinforcement panel in the frontal area (e.g. reinforcement panel in the bonnet closure area, support panels for radiator, headlights and other assemblies in the front area etc.).

A further application which is not known in this manner in body construction can also be "curtain-type" protective panels. In this case the improved bending

behaviour which is achieved is particularly important as, on an impact, it prevents cracking or splintering in the folds, further minimising the risk of injury.

Further advantages, features and details of the invention arise from the description below of preferred embodiment examples and with reference to the drawing which shows:

- Fig. 1 a diagram with the yield strength of a first and a second aluminium alloy in different ageing states;
- Fig. 2 a diagram with the differences between the yield strength of the first and second aluminium alloys of fig. 1 in different ageing states and the yield strength of the alloys in delivery state T4;
- Fig. 3 and 4 pictures taken from metal cuts of sheet samples with different part of precipitated Mg_2Si particles under a scanning electron microscope (SEM) in compo modus;
- Fig. 5 the dependence of the yield strength on the volume part of precipitated Mg_2Si particles of an AlMgSi alloy by means of a model calculation.

Example 1

From a first aluminium alloy A (AA 6016) and a second aluminium alloy B with the chemical compositions given in table 1, strips of thickness 1.2 mm were produced in a conventional manner by vertical continuous casting, homogenisation annealing, hot and cold rolling.

Table 1

Alloy	Si	Fe	Cu	Mr	Mg	Cr	Zn	Ti	V
A	1.14	0.21	0.08	0.07	0.55	0.013	0.003	0.033	<0.005
B	0.42	0.17	0.08	0.07	0.40	0.018	<0.003	0.024	0.006

The strips were subjected to solution annealing (alloy A) and partial solution annealing (alloy B) in a strip passage annealing oven, then quenched by moving air and artificially aged for several days at room temperature to delivery state T4. For the two aluminium alloys A and B the following solution annealing conditions were selected:

Alloy A	550°C / 30 seconds
Alloy B	500°C / 20 seconds

A paint baking cycle was simulated on sheet samples of aluminium alloys A and B in delivery state T4, with annealing at a temperature of 185°C for a period of 20 min. To test the influence of cold forming (CF) on the yield strength $R_{p0.2}$, tensile strength R_m and elongation at fracture A_{80}, the sheet samples in delivery state were 2% further cold formed. A further series of specimens were 2% cold formed in delivery state and then subjected to the above-mentioned annealing treatment.

The mechanical strength values given in table 2 for the two aluminium alloys A and B in the various states tested, and the values also shown graphically in figs. 1 and 2 for the yield strength $R_{p0.2}$, for both aluminium alloys A and B in delivery state with 2% cold forming, show a slight and proportionally approximately equal increase in yield strength. If merely a paint baking annealing is performed at the delivery state, for alloy A there is a clear increase in the yield strength whereas for alloy B there is practically no artificial ageing effect. The differing behaviour of the two aluminium alloys A and B under paint baking conditions is even clearer under combined application of cold forming 2% with subsequent annealing at 185°C for 20 minutes, as often occurs in practice in the production of car body parts.

Table 2

Alloy	State	$R_{p0.2}$ [MPa]	R_m [MPa]	A_{80} [%]	$\Delta R_{p0.2}$ [MPa]
A	Delivery state T4	115	225	25.4	
	185°C x 20 min	195	271	20.8	80
	2% CF	140	251	24.3	25
	2% CF + 185°C x 20 min	245	295	15.4	130
B	Delivery state T4	70	129	27.7	
	185°C x 20 min	74	130	25.9	4
	2% CF	90	133	25.3	20
	2% CF + 185°C x 20 min	94	149	18.6	24

Example 2

On 2 tensile test pieces of alloy B in example 1 having a thickness of 0,85 mm and a width of 12,5 mm in different artificial ageing conditions tensile strength R_m, yield strength $R_{p0.2}$ and elongation at fracture A_{50} have been determined in tensile tests. The examined artificial ageing treatments are given in Table 3. The solution annealing was carried out in a salt bath at the given temperature for the given time. Subsequently the test pieces were quenched in water, aged for 24 h at room temperature and subsequently aged for 24 h at a temperature of 65 °C. This ageing treatment leads to a simulated T4 condition. A part of these test pieces A to L was given an artificial ageing treatment at 205 °C for 1 h, corresponding to a T6 condition.

Table 3

Test piece	Solution annealing
A	520 °C / 5 s
B	520 °C / 10 s
C	530 °C / 0 s
D	530 °C / 5 s
E	530 °C / 10 s
F	530 °C / 20 s
G	540 °C / 0 s
H	540 °C / 5 s
I	540 °C / 10 s
J	540 °C / 20 s
K	540 °C / 60 s
L	540 °C / 10 min

The results of tensile tests carried out on 2 test pieces each are given in table 4 for the test pieces in the T4 condition and in table 5 for the test pieces in the T6 condition.

Table 4

Test piece	$Rp_{0.2}$ [MPa]	R_m [MPa]	A_{50} [%]
A1	43,9	115,6	16,3
A2	44,6	114,5	23,3
B1	43,9	114,9	20,2
B2	44,2	117,3	23,2
C1	44,1	116,4	24,2
C2	40,6	112,9	26,8
D1	45,2	114,8	30,9
D2	43,6	116,0	22,0
E1	44,0	119,5	15,6
E2	45,3	117,2	25,5
F1	48,5	125,2	19,0
F2	48,4	124,9	26,6
G1	41,5	112,1	26,1
G2	42,9	111,1	25,1
H1	43,7	115,3	25,1
H2	43,9	114,0	20,2
I1	44,0	119,0	21,7
I2	45,3	118,7	24,9
J1	48,3	127,6	15,1
J2	47,6	126,1	24,4
K1	56,8	137,8	15,6
K2	56,4	137,9	16,2
L1	63,1	152,4	20,7
L2	61,7	144,1	18,1

Table 5

Test piece	$Rp_{0.2}$ [MPa]	R_m [MPa]	A_{50} [%]
A1	47,1	117,2	25,1
A2	46,5	116,1	21,6
B1	52,5	119,9	24,8
B2	54,3	123,4	25,3
C1	40,9	111,0	26,1
C2	41,4	111,2	27,9
D1	49,9	119,6	24,4
D2	53,2	120,4	25,2
E1	50,6	121,4	25,3
E2	57,2	123,5	23,9
F1	61,5	130,9	24,7
F2	61,7	129,1	22,9
G1	44,7	114,1	28,1
G2	44,0	113,3	26,5
H1	45,4	119,9	20,5
H2	47,5	118.4	19,2
I1	55,6	125,7	25,0
I2	52,6	124,5	25,4
J1	65,9	135,1	18,5
J2	64,5	135,1	18,9
K1	98,3	154,6	10,6
K2	98,2	153,5	11,3
L1	138,4	177,3	9,0
L2	137,4	178,0	11,4

From the test pieces C and L in table 4 metal cuts have been made. Under a scanning electron microscope in the compo modus the volume part of the precipitated Mg_2Si particles related to the total volume has been determined by measuring the corresponding area parts in 12 area regions. Particles having a diameter < 0,1 µm are designated as precipitated Mg_2Si particles.

The mean values for the test piece C resulted in a volume part of 0,444 ± 0,077 % corresponding to a part of about 50 % of the theoretically possible Volume part. For the test piece L the mean values resulted in a volume part of 0,071 ± 0,029 % corresponding to a part of about 8 % of the theoretically possible volume part.

The SEM picture in compo modus of test piece C shown in fig. 3 and of test piece L shown in fig. 4 let the heavy iron containing precipitates appear as bright spots and the light-weight Mg_2Si particles as dark spots. The higher volume part of precipitated Mg_2Si particles of test piece C in comparison with test piece L is clearly perceptible.

With the values for the yield strength $R_{p0.2}$ measured on the test pieces A to L of table 5 the dependence of the yield strength $R_{p0.2}$ on the volume part of the precipitated Mg_2Si particles has been determined by means of a model calculation and is graphically shown in fig. 5. The values on the x-axis correspond to the ratio of the volume part of the Mg_2Si pre-precipitates to the theoretically possible volume part.

The diagram clearly shows that the yield strength $R_{p0.2}$ selected here as a measure for the "softness" of the alloy can be varied within broad limits by controlling the pre-precipitation of Mg_2Si.